

**THERMOPLASTIC SHEET ABRASIVES AND
METHODS OF MAKING THE SAME**

FIELD OF THE INVENTION

The present invention relates generally to the field of sheet abrasives. More particularly, the invention relates to sheet abrasives comprising abrasive particles dispersed within a thermoplastic polymer and methods for making the same.

5 **BACKGROUND**

Conventional sheet abrasives generally consist of abrasive particles bonded to the surface of a paper or cloth base material. These types of coated sheet abrasives, however, suffer from several disadvantages. Typically, a coated sheet abrasive contains a single layer of abrasive particles coated on the base material, which itself is non-abrasive. During use, the abrasive particles are either worn down or become detached from the surface of the base material, leaving only bare base material in contact with the work surface. Thus, the useful life of these types of sheet abrasives is limited by the thickness of the abrasive particle layer and by the strength of the bond between the abrasive particles and the base material. In addition, the flexibility of conventional coated sheet abrasives is limited because bending or stretching the sheets can dislodge the abrasive particles from the base material and crack, crease, or otherwise damage the sheet.

Abrasive sheets made of abrasive particles dispersed within a polymer are known. In some cases, these sheets are formed by mixing the abrasive particles and the polymer in an organic solvent, and subsequently evaporating the solvent. Storing, handling, and transporting the organic solvents used in this process pose a significant inconvenience and health hazard to operators. Furthermore, evaporating the organic solvents can make the process more costly and time consuming.

In other cases, abrasive particles are mixed with a polymer in solid form, and the mixture is compression molded to form a pad with a plurality of abrasive protrusions. The compression molding process is time consuming because the process is non-continuous, *i.e.*, each mold can only produce one abrasive pad at a time.

Therefore, there is a need for flexible sheet abrasives having increased durability and mechanical strength that can be produced in an efficient, cost-effective manner.

SUMMARY OF THE INVENTION

5 The present invention provides a sheet abrasive that includes a plurality of abrasive particles dispersed within a thermoplastic polymer layer. The thermoplastic polymer layer preferably is an extruded thermoplastic polymer layer or an injection-molded thermoplastic polymer layer. The thermoplastic polymer layer makes the sheet abrasive strong yet flexible, and the abrasive particles are held firmly in place within the polymer layer without the need for an additional bonding material. Furthermore, because the abrasive particles are dispersed
10 throughout the thickness of the thermoplastic polymer layer, not just on its surface, the sheet abrasive maintains its abrasive qualities even after its topmost layer has been worn away.

The thermoplastic polymer layer can include, but is not limited to, polyamides, polyurethanes, acetals, thermoplastic polyimides, liquid crystal polymers, polyphenylene sulfides, polyetheramides, polyetheresters, polyethylene, or combinations thereof. In addition,
15 the thermoplastic polymer layer may be a foamed polymer. The thermoplastic polymer may be an extruded thermoplastic polymer or an injection-molded thermoplastic polymer. The extruded thermoplastic polymer layer can be uni-axially or bi-axially oriented. The sheet abrasive preferably has a thickness ranging from about 0.001 inch to 0.25 inch.

The abrasive particles can include, but are not limited to, silicon carbide, aluminum
20 oxide, diamond, ceramic aluminum oxide, ceramic, zirconia aluminum, garnet, cubic boron nitride, talc, and combinations thereof. The abrasive particles can be dispersed substantially uniformly within the thermoplastic polymer layer. The abrasive particles can comprise from about 1% to about 30% by volume of the sheet abrasive.

The sheet abrasive can contain a second layer, such as a polymer layer, adjacent to the
25 thermoplastic polymer layer. The second layer also may contain a plurality of abrasive particles. An adhesive layer may be disposed between the thermoplastic polymer layer and the second layer. Sheet abrasives of the invention can be adapted to form a continuous belt or a flap wheel.

The present invention also provides methods of forming sheet abrasives of the invention that include the steps of dispersing a plurality of abrasive particles in a thermoplastic polymer

and either extruding the thermoplastic polymer to form an extruded thermoplastic polymer layer or injecting the thermoplastic polymer into a mold to form an injection-molded thermoplastic polymer layer. The thermoplastic polymer layer preferably is extruded or molded to a thickness ranging from about 0.001 inch to 0.25 inch. An extruded thermoplastic polymer layer can be oriented either uni-axially or bi-axially, for example, by stretching.

A second layer can be provided adjacent to the thermoplastic polymer layer. The second layer can be a polymer and/or contain a plurality of abrasive particles. The second layer can be co-extruded with an extruded thermoplastic polymer layer, or the second layer can be adhered to the extruded thermoplastic polymer layer with an adhesive. The second layer can be co-molded with an injection-molded thermoplastic polymer layer, or the second layer can be present within the mold prior to injecting the molten thermoplastic polymer, or the second layer can be adhered to the injection-molded thermoplastic polymer layer with or without an adhesive.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is pointed out with particularity in the appended claims. The advantages of the invention can be better understood by reference to the description taken in conjunction with the accompanying drawings.

The drawings are not necessarily to scale, emphasis instead generally being placed upon illustrating the principles of the invention. In the drawings, like reference characters generally refer to the same parts throughout the different views.

FIG. 1A is a schematic cross-sectional views of an embodiment of a sheet abrasive.

FIG. 1B is a schematic cross-sectional view of the sheet abrasive of FIG. 1A after use.

FIG. 2 is a schematic cross-sectional view of another embodiment of a sheet abrasive.

FIG. 3 is a schematic cross-sectional view of an embodiment of a sheet abrasive that includes a thermoplastic polymer layer and a second layer.

FIG. 4 is a schematic representation of an embodiment of an extruder for producing sheet abrasives.

DETAILED DESCRIPTION

Throughout the description, where compositions are described as having, including, or comprising specific components, or where processes are described as having, including, or comprising specific steps, it is contemplated that compositions of the invention also consist essentially of, or consist of, the recited components, and that the processes of the invention also consist essentially of, or consist of, the recited steps.

As illustrated by FIG. 1A, a sheet abrasive **2** according to one embodiment of the invention includes a plurality of abrasive particles **4A**, **4B** dispersed within a thermoplastic polymer layer **6**. The abrasive particles can be dispersed substantially uniformly throughout the thickness of the thermoplastic polymer layer, or they can be dispersed in a non-uniform fashion. For example, the concentration of abrasive particles may be greater near one or more surfaces of the thermoplastic polymer layer.

With reference to FIG. 1A, a portion of the abrasive particles may be located at or near a surface **8** of the thermoplastic polymer layer **6** (e.g., abrasive particle **4A** in FIG. 1A) with other abrasive particles located in the interior **10** of the thermoplastic polymer layer **6** (e.g., abrasive particle **4B** in FIG. 1A). During use, friction between the surface of the sheet abrasive and a work surface wears away portions of the thermoplastic polymer layer and any abrasive particles embedded therein. As the thermoplastic polymer layer **6** is worn away, an abrasive particle **4B** that was previously in the interior **10** of the thermoplastic polymer layer **6** is exposed, as illustrated by FIG. 1B. Thus, unlike conventional coated sheet abrasives, which are no longer useful once their topmost abrasive layers have worn away, a sheet abrasive of the invention maintains its abrasive qualities after portions of the thermoplastic polymer layer are worn away, thereby increasing the useful life of the sheet abrasive.

In some embodiments of a sheet abrasive, a portion of the abrasive particles are located at more than one surface of the thermoplastic polymer layer. For example, in the illustrative embodiment shown in FIG. 2, the abrasive particle **4A** is located at one surface **8** of the thermoplastic polymer layer **6**, and the abrasive particle **4C** is located at the other surface **12**. The remaining abrasive particle **4B** is located in the interior **10** of the thermoplastic polymer layer **6**. In this embodiment, both surfaces **8**, **12** of the sheet abrasive **2** can perform work on one or more work surfaces.

The thermoplastic polymer layer can be any thermoplastic polymer known in the art. Suitable materials include, for example, polyamides, polyesters, polyoxymethylenes, polyethylene, ethylene copolymers, ethylene acrylic acid copolymers, ethylene acrylate copolymers, ethylene methacrylic acid copolymers, ethylene vinyl alcohol copolymer, ethylene vinyl acetate copolymers, polyphenylene ether, polyphenylene oxide, polyphthalamide, polypropylene, polystyrene, polyacrylonitrile, polyurethanes, rubbery polymers (such as, for example, ethylene propylene rubbers and ethylene propylene diene rubbers), polyvinyl chloride, styrene acrylonitrile, acrylonitrile butadiene styrene, styrene butadiene, styrene maleic anhydride, polycarbonate, polyurethanes, acetals, acrylics, cellulose acetate butyrate, cellulose acetate propionate, fluoropolymers (such as, for example, polyvinylidene fluoride (PVDF), perfluoroalkoxy (PFA), ethylene tetrafluoroethylene (ETFE), fluorinated ethylene propylene (FEP), chlorotrifluoroethylene (CTFE), and polytetrafluoroethylene (PTFE)), ionomers, liquid crystal polymers, polyphenylene sulfide, polyamide imide, thermoplastic polyimides, polyarylate, polybutylene, polyaryletherketone, polyetherether ketone, polyetherketones, polyetherimides, polyethersulfone, polysulfone, thermoplastic elastomers, polyetheramides, polyetheresters, diallyl phthalate, melamine phenolic, phenolics, and unsaturated polyesters.

Alternatively, the thermoplastic polymer layer can include a combination, blend or alloy of one or more polymers as described above. Polymer blends or alloys can include one or more polymers suspended in another polymer, one or more polymers dissolved in another polymer, or a mixture of suspended and dissolved polymers. The blends or alloys can be miscible or immiscible. Sheet abrasives can also be formulated such that the thermoplastic polymer layer can be subsequently cross-linked or cured in a secondary operation, if desired, in order to maximize certain properties such as heat resistance, toughness or elasticity.

In some embodiments, the thermoplastic polymer layer is foamed. Foaming makes the thermoplastic polymer lightweight and shock-absorptive. One method for foaming a polymer is by the addition of one or more blowing agents to the polymer prior to forming an abrasive sheet. A blowing agent is a solid or a fluid that causes bubbles, for example, gas bubbles, to form within the polymer, which expand as the molten polymer cools. Examples of blowing agents include foaming agents such as Foamazol® 72 and Foamazol® XO-227 (Bergen International,

Rochelle Park, New Jersey). Gaseous blowing agents include inert gases such as nitrogen and argon.

The abrasive particles generally have a Knoop scale hardness value that is greater than the thermoplastic polymer layer. Suitable materials include, for example, aluminum oxide, silicon carbide, zirconia aluminum, ceramic aluminum oxide, natural and artificial diamond, glass beads, calcium oxide, talc, clay, ceramic, fiberglass, silica, wood fillers, nut shells, apatite, feldspar, tool steel, quartz, chromium, zirconium, beryllia, topaz, garnet, zirconium boride, titanium nitride, tungsten carbide, tantalum carbide, zirconium carbide, alumina, beryllium carbide, titanium carbide, silicon carbide, aluminum boride, cubic boron carbide, cubic boron nitride, emery, spinel, flint, and mixtures thereof.

One example of a suitable mixture of abrasive particles is a mixture of silicon carbide and aluminum oxide. In addition, aggregates or multiple abrasive particles fused together by a bonding agent can be used. The abrasive particles may be completely or partially coated by an inorganic or metallic coating material. Examples include nickel-coated diamond and copper-coated diamond. The abrasive particles may be coated with a coupling agent, such as a silane coupling agent (*e.g.*, 3-aminopropyl-triethoxysilane) to increase the adhesion of the abrasive particles to the thermoplastic polymer layer. The abrasive particles can have any size or shape, although preferably the abrasive particles are small enough to be contained entirely within the thickness of the thermoplastic polymer layer. Mixtures of different sized of abrasive particles can be used, such as, for example, a mixture of 46 mesh and 120 mesh silicon carbide.

The abrasive particles can comprise from about 1% to about 50% by volume of the thermoplastic sheet abrasive, from about 1% to about 40% by volume of the thermoplastic sheet abrasive, or from about 1% to about 30% by volume of the thermoplastic sheet abrasive. In some embodiments, the abrasive particles comprise up to 25% by volume, or up to 35% by volume, or up to 45% by volume of the thermoplastic sheet abrasive. The amount of abrasive particles found in sheet may be higher than 50% by volume depending on the particular characteristics of the abrasive particles and/or the thermoplastic polymer used to form the thermoplastic sheet abrasive.

In addition to abrasive particles, one or more additives known in the art can be included in a sheet abrasive. Examples of additives include colorants, tougheners (including rubber

tougheners), plasticizers, fillers, reinforcements, lubricants, anti-blocking compounds, process aids, stabilizers, and blowing agents.

Sheet abrasives in accordance with the invention can be produced by any conventional thermoplastic processing method, including molding and extrusion. It should be understood that in any of the methods described and claimed herein, the steps can be performed in any order, or one or more steps can be performed simultaneously, as long as the method remains operable.

In a preferred method, sheet abrasives are produced by an extrusion method. Extrusion methods can produce sheet abrasives of any length, and the sheets can conveniently be wound onto rolls. The extrusion process generally involves adding one or more thermoplastic polymers, abrasive particles, and any additional polymers and/or additives into a thermoplastic melt-mixing device. The components are transported through the device, for example, using a screw, toward a die which is cut in the shape of the desired product. As the thermoplastic polymer(s) move within the device, they begin to melt into a softer flowing material and mix with the other components. The molten thermoplastic polymer mixture is forced through the die, yielding a polymer extrudate. The extrudate then is quenched or solidified, typically using a rollstack device. Alternatively, the extrudate may be quenched or solidified using air or a water bath. Additional finishing steps may include removing excess water using an air blower and/or threading the extrudate through pinch rolls to control its width or diameter. After quenching, the sheet abrasive can be cut to desired lengths and/or wound onto rolls.

Examples of suitable extrusion devices include single-screw extruders, twin-screw extruders, brabender type mixers, and kneaders, some of which are commercially available from Battenfeld Gloucester (Gloucester, Massachusetts) and Davis Standard (Pawcatuck, Connecticut). The surfaces of the extruder and other processing equipment that come into contact with the sheet abrasives can be modified with hardened surfaces or liners to prevent wear and increase the useful life of the extruder.

In some embodiments, after the sheet abrasive has been extruded and quenched or solidified, it is subjected to an orientation process to increase the tensile strength of the sheet. Orientation generally involves stretching or compressing the sheet abrasive at a temperature above the polymer's glass transition temperature, but below its crystalline melting temperature. Orientation can be uni-axial, typically by stretching or compressing the sheet along its length

(*i.e.*, in the casting machine direction), or bi-axial, typically by also stretching or compressing the sheet in a transverse direction (*i.e.*, in a cross machine direction). Bi-axial orientation is typically done using a tenter frame or compression or nip rolls. In some embodiments, the entire sheet abrasive can be oriented, while in other embodiments, one or more portions of the sheet abrasive are oriented and other portions are not. Suitable equipment for orienting sheet abrasives is commercially available from Marshall and Williams Plastics (Woonsocket, Rhode Island), Battenfeld Gloucester (Gloucester, Massachusetts), and Davis Standard (Pawcatuck, Connecticut).

Molded sheet abrasives preferably are prepared by compression or injection molding. In compression molding, a thermoplastic polymer is placed into a mold which is subsequently closed and held at a high pressure. The mold is heated to fuse the thermoplastic polymer, and after an appropriate time, the mold is opened and the product removed. In contrast, injection molding involves injecting a molten thermoplastic polymer into a closed mold. The molten polymer cools and hardens into shape within the mold, which then is opened to remove the product. Any materials and methods used in compression or injection molding known in the art may be used to form sheet abrasives in accordance with the invention.

The cross-sectional shape of a sheet abrasive can be tailored to suit its particular application. In some embodiments, the sheet abrasive has the form of a film, strip, or tape, *i.e.*, its width and length are greater than its thickness. However, thermoplastic abrasives can be formed into any shape to adapt to any particular application, for example, a block or o-ring shape. For sheet abrasives produced by an extrusion process, the cross-sectional shape is determined by the shape of the extrusion die. For a molding process, the shape of the mold determines the cross-sectional shape of sheet abrasives. In either process, the cross-sectional shape can be further modified by thermal, chemical, and/or mechanical means after the thermoplastic polymer has been extruded or molded. A sheet abrasive can have any cross-sectional shape, including, for example, quadrilateral, round, and oval.

In some embodiments, a sheet abrasive according to the invention has a thickness ranging from about 0.0005 inch to about 0.25 inch. In other embodiments, a sheet abrasive has a thickness ranging from about 0.001 inch to about 0.25 inch, or from about 0.001 inch to about 0.125 inch. In other embodiments, a sheet abrasive has a thickness ranging from about 0.001

inch to about 0.05 inch. In still other embodiments, a sheet abrasive has a thickness ranging from about 0.005 inch to about 0.03 inch.

5 In the illustrative embodiment shown in FIG. 3, a sheet abrasive **20** includes a second layer **22** adjacent to a thermoplastic polymer layer **24** which contains a plurality of abrasive particles **26**. The second layer can serve to enhance various properties of the abrasive sheet, including, for example, stiffness, toughness, resilience, abrasion resistance, coefficient of friction, heat stability, chemical resistance, hydrolysis resistance, oxidative stability, heat conductivity, anti-static properties, electrical conductivity, and/or thermal coefficient of expansion. The second layer can be made of any material, including, for example, paper, cloth,
10 metal, polymer, or combinations thereof. The second layer can have various forms, including, for example, a continuous sheet, a fibrous woven or non-woven belt, a web or mesh, or a layer of abrasive particles.

Suitable metals for use in a second layer include, for example, aluminum, chromium, steel, and alloys thereof. Any of the polymers or combination of polymers described above in
15 connection with the thermoplastic polymer layer can be used to form the second layer. In addition, the second layer can include any of the abrasive particles and/or additives described above. In some embodiments, the second layer contains the same type and/or amount of abrasive particles and/or additives as the thermoplastic polymer layer. In other embodiments, the second layer and the thermoplastic polymer layer contain different types and/or amounts of
20 abrasive particles and/or additives.

The second layer can be bonded to the thermoplastic polymer layer using an adhesive, or the second layer can be coated or sprayed onto to the thermoplastic polymer layer. In cases where the second layer includes a polymer, the second layer can be extruded onto the thermoplastic polymer layer, or the second layer and an extruded thermoplastic polymer layer
25 can be co-extruded. A co-extrusion process involves extruding two or more layers simultaneously by combining the extrudates from multiple extruders into a manifold and extruding through a special multi-layer die. Alternatively, the second layer can be present within a mold prior to injecting a molten thermoplastic layer into the mold. Each layer can have the same or different widths, and the layers may be offset.

The second layer can have the same thickness as the thermoplastic polymer layer, or the two layers can have different thicknesses. That is, the thermoplastic polymer layer can have a thickness greater than the thickness of the second layer, or the thermoplastic layer can have a thickness less than the thickness of the second layer. The second layer and the thermoplastic polymer layer can have the same shape and/or size, or their shapes and/or sizes may differ.

In some embodiments, the second layer and the thermoplastic polymer layer are aligned so that the second layer is adjacent to substantially all of a surface of the thermoplastic polymer layer. In other embodiments, the second layer and the thermoplastic polymer layer are offset, so that at least one portion of the thermoplastic polymer layer is not adjacent to the second layer.

This embodiment is particularly useful for sheet abrasives that are extruded and wound into rolls.

The present invention also contemplates sheet abrasives that contain further layers in addition to a thermoplastic polymer layer and a second layer. For example, a sheet abrasive may include a third layer, a fourth layer, a fifth layer, a sixth layer, a seventh layer, an eighth layer, and so on. The additional layers can be disposed adjacent to any other layer. For example, in a sheet abrasive that contains a thermoplastic polymer layer, a second layer, and a third layer, the third layer can be adjacent to either the thermoplastic polymer layer or the second layer. The additional layers can have some or all of the characteristics and properties described above for the second layer and can be made by the same processes and techniques described above.

Sheet abrasives in accordance with the invention can be used in a variety of ways similar to conventional coated abrasives, such as emery cloth or sand paper. In addition, the sheet abrasives can be thermoformed into a variety of shapes heretofore unobtainable with conventional coated abrasives to create new tools engineered to fit specific applications. Thermoforming involves applying heat and/or pressure to a sheet abrasive to form the sheet into a different three-dimensional shape. For example, in one embodiment according to the invention, a thermoplastic sheet abrasive is thermoformed to fit over the end of a pipe (*e.g.*, similar to the shape of a lid for a disposable drinking cup). The resulting thermoformed abrasive then can be used as a de-burring or polishing tool for the end of like-sized metal pipes.

In one embodiment, an adhesive polymer layer is disposed between a thermoplastic polymer layer containing a plurality of abrasive particles and a second layer that provides reinforcement, toughening or other attributes. In a variation of this embodiment, the second

layer is a removable backing or liner, which, when removed, exposes the adhesive layer which remains disposed on the thermoplastic polymer layer. The sheet abrasive can then be adhered to another surface using the adhesive layer. In a related embodiment, the second layer is a fastening system, for example, a hook and loop device (*e.g.*, Velcro®), which can be used to fasten the sheet abrasive to another surface.

In other embodiments of a sheet abrasive, the thermoplastic polymer layer includes a thermoplastic elastomer, such as, but not limited to, soft polyurethanes, polyetheresters, or polyetheramide esters. The sheet abrasive is very flexible and can be used on curved surfaces (*e.g.*, contours of molding, metal rods, etc.) that cannot effectively be sanded by conventional coated abrasives.

In some embodiments, the second layer is foamed to provide for shock absorption, insulation, or sound damping qualities. In other embodiments, the second layer includes fiberglass or clay to provide enhanced stiffness. The second layer may include a high thermal conductivity filler to enhance cooling of the sheet abrasive. In other embodiments, the second layer includes tungsten or other high density fillers to provide a sheet abrasive with increased weight for use in flapwheel-type applications. In yet other embodiments, an intermediate layer is extruded between two thermoplastic polymer layers containing a plurality of abrasive particles to produce an abrasive sheet construction with abrasive on the top and bottom with a reinforcing or toughening layer in between. It is to be understood that, in addition to the embodiments described above, a sheet abrasive in accordance with the present invention can have any configuration of thermoplastic polymer layer, second layer, and/or additional layers.

Sheet abrasives in accordance with the invention can be cut to any desired length or shape and used directly, like conventional sand paper, or they can be formed into implements or tools. For example, a sheet abrasive can be cut and the ends joined using conventional bonding or joining techniques to form belts. Alternatively, a sheet abrasive can be cut into flaps and formed into star pads, cross pads, square pads, flap wheels, flap discs, cartridge rolls, spiral bands, overlap discs, overlap cones, and other implements known in the art. Examples of implements that can be formed using sheet abrasives according to the invention can be found in the catalogue, "3M Grindline Express Coated Abrasive, Surface Conditioning, and Superabrasive Products 1996" (3M Company, Minneapolis, Minnesota).

EXAMPLES

The following examples are meant to illustrate, not limit, the scope of the present invention.

Example 1

5 All examples were produced using the extruder **30** illustrated schematically in FIG. 4. The polymer starting materials were added to the rear of the extruder **30** through primary feeder **32**, and the abrasive particles were added through secondary feeder **34**. The extrudate **36** exited the die **38** vertically downward into a water quench bath **40** where the extrudate **36** was solidified. A standard 6 inch film type die **38** with an adjustable die gap (Extrusion Dies Inc.,
10 Chippewa Falls, Wisconsin) was used. The die gap was set at 0.058 inch for all examples. The extrudate **36** was pulled by a set of slow group orientation rolls **42**, and was passed through an orientation oven **44** and then onto a set of fast group orientation rolls **46**. Next, the extrudate **36** was passed through a relaxation oven **48**, a set of crimp rolls **50** to provide crimp, and then through a set of lube rolls **52** coated with a lubricant. The extrudate **36** then was passed onto a
15 set of relaxation group rolls **54**, which were set at the same speed as the fast group orientation rolls **46**. Finally, the extrudate **36** was wound onto a collection reel **56**.

The extrusion conditions are listed in Table 1. Samples A, B, C, D and the control sample included nylon 6 (Ultramid® B3 Natural, BASF, Ludwigschafen, Germany), and samples E and F included nylon 6/12 (Zytel® 158, DuPont, Wilmington, Delaware). All nylons
20 were dried for four hours at 175° F for four hours just prior to extrusion. All samples except for the control included 120 mesh aluminum oxide abrasive particles (Norton Abrasives, Worcester, Massachusetts). The compositions are listed in weight percent as determined by pyrolysis and gravimetric analysis of the residual aluminum oxide.

Table 1

	Control	Sample A	Sample B	Sample C	Sample D	Sample E	Sample F
Polymer	100% Nylon 6	60% Nylon 6	60% Nylon 6	54% Nylon 6	54% Nylon 6	40% Nylon 6/12	40% Nylon 6/12
Abrasive	0%	40%	40%	46%	46%	60%	60%
Extruder Temp.							
Zone 1	514°F	514°F	514°F	514°F	514°F	514°F	514°F
Zone 2	516°F	516°F	516°F	516°F	516°F	516°F	516°F
Zone 3	511°F	511°F	511°F	511°F	511°F	511°F	511°F
Zone 4	500°F	500°F	500°F	500°F	500°F	500°F	500°F
Zone 5	511°F	511°F	511°F	511°F	511°F	511°F	511°F
Zone 6	504°F	504°F	504°F	504°F	504°F	504°F	504°F
Zone 7	518°F	518°F	518°F	518°F	518°F	518°F	518°F
Zone 8	523°F	523°F	523°F	523°F	523°F	523°F	523°F
Zone 9	511°F	511°F	511°F	511°F	511°F	511°F	511°F
Zone 10	509°F	509°F	509°F	509°F	509°F	509°F	509°F
Zone 11	500°F	500°F	500°F	500°F	500°F	500°F	500°F
Zone 12	500°F	500°F	500°F	500°F	500°F	500°F	500°F
Zone 13	510°F	510°F	510°F	510°F	510°F	510°F	510°F
Die Temp.	520°F	520°F	520°F	520°F	520°F	520°F	520°F
Extruder RPM	38	38	38	38	38	38	38
Roller Speed (RPM)							
Slow group	79	79	72	72	79	80	80
Fast group	104	104	144	144	104	80	88
Relaxation group	104	104	144	144	104	80	88
Orientation Ratio	1.3	1.3	2.0	2.0	1.3	1.0	1.1
Sheet Thickness (inches)	0.007	0.016	0.015	0.015	0.017	0.025	0.024

Test strips (1.0 inch wide by 12 inches long) of each sample were prepared. For comparative purposes, a test strip made from a commercial non-woven abrasive strip, Standard B/T Belt, SCF-FE containing 120 mesh aluminum oxide (Standard Equipment Company, Mobile, Alabama), was also prepared. Each test strip was rubbed for 6 strokes (3 in each direction) using light hand pressure (about 5 lbs. or off-hand application) over a 1.5 inch diameter copper pipe. The contact length on the pipe was controlled at 2 inches, with 5 inches of each test strip contacting the pipe. The polishing ability of each sample was ranked from 0 to 5, with 0 being poor or no polish and 5 being high polish. The test results are shown in Table 2.

Referring to Table 2, the control sheet which contained no abrasive particles had no polishing affect on the copper pipe. The commercial abrasive strip produced very modest polishing results, while samples A-F produced good polishing results. The polishing results appeared to improve in proportion to the percent of abrasive particles in the strips. This experiment demonstrates that sheet abrasives in accordance with the present invention can produce polishing results comparable with or better than commercially available non-woven abrasive materials.

Table 2

Sample	Polymer	% Abrasive	Polishing Rank
Control	Nylon 6	None	0
Standard B/T Belt SCF-FE	SCF-FE	Unknown	1
A	Nylon 6	40%	3
B	Nylon 6	40%	2
C	Nylon 6	46%	3
D	Nylon 6	46%	3.5
E	Nylon 6/12	60%	4
F	Nylon 6/12	60%	4

Example 2

A two layer sheet abrasive sample was prepared by adhering a control sheet made of nylon 6 onto sample F using hot melt glue. The resulting two-layer sheet abrasive sample could not be torn by hand, while Sample E, which did not contain a second layer, could be torn with moderate effort. This experiment demonstrates sheet abrasives that include two or more layers can exhibit improved mechanical properties, such as improved tensile strength.

The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The foregoing embodiments are therefore to be considered in all respects illustrative rather than limiting on the invention described herein. Scope of the invention is thus indicated by the appended claims rather than by the foregoing description, and
5 all changes that come within the meaning and range of equivalency of the claims are intended to be embraced therein.